



Ride Quality Index – A New Approach to Quantifying the Comparison of Acceleration Responses of High Speed Craft

**Multi-Agency Craft Conference
Virginia Beach, Virginia
14 – 16 June 2011**

**Michael Riley, Dr. Tim Coats
Kelly Haupt, Don Jacobson**

Combatant Craft Division

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JUN 2011		2. REPORT TYPE		3. DATES COVERED 00-00-2011 to 00-00-2011	
4. TITLE AND SUBTITLE Ride Quality Index-A New Approach To Quantifying The Comparison Of Acceleration Responses Of High Speed Craft				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NAVSEA Warfare Centers, Carderock, West Bethesda, MD, 20817				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES Presented during the Multi-Agency Craft Conference (MACC) 2011, June 14-16, 2011, Joint Expeditionary Base, Fort Story-Little Creek, Virginia Beach, VA					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 23	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

Outline



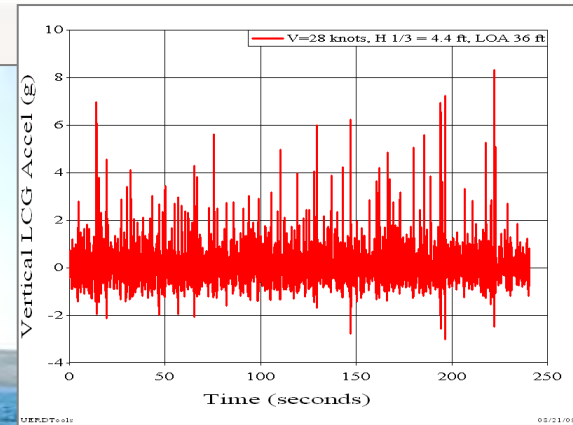
Dr. Paul Rispin
ONR 331

- Background
- Objective
- Repeatable $A_{1/n}$ Calculations
- Ride Quality Index
- Wave Slam Damage Potential
- Example Comparisons
- Summary

Background

- Historical perspective (1950's – early 1970's)
 - Passenger comfort studies for airplanes, cars, trains
 - Ride quality linked to vibrations, temperature, noise
 - RMS acceleration values used to quantify vibration amplitudes
 - Applied to displacement hulls, surface effect ships, hydrofoils
- NSWCCD mid-1970's: RMS values reported not applicable when craft motions include shocks or impulsive velocity changes
 - Dissatisfaction with general lack of ride quality data
 - Lack of fully satisfactory criteria for judging ride quality in rough seas
 - No standard process for acquiring and processing data

Objective

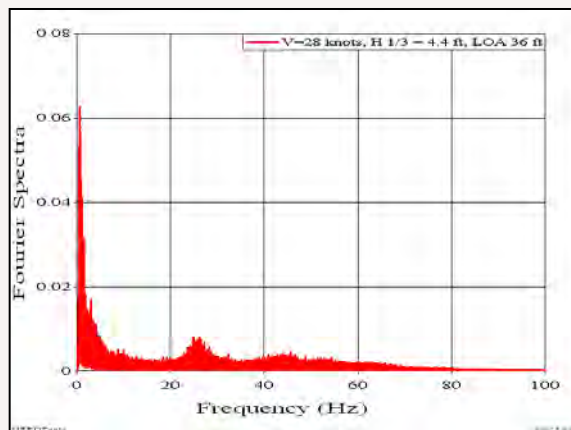


To present a simplified approach to quantifying ride quality when comparing wave impacts for different craft, different sea states, different speeds, or different gage locations.

$A_{1/n}$ Calculation Process

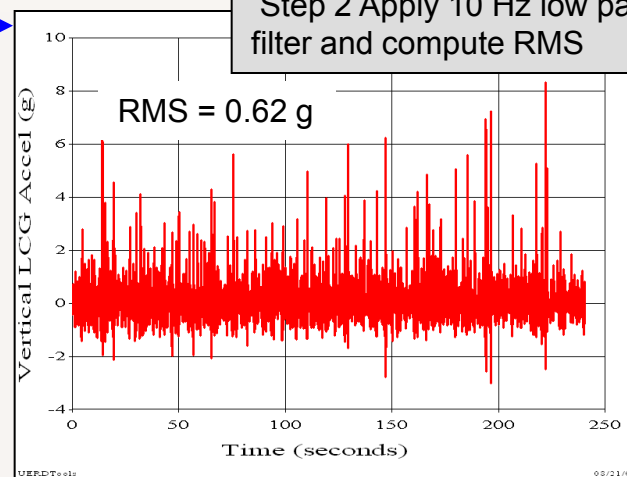
Unambiguous statistical calculations

Step 1 Compute spectrum of unfiltered record



Use spectrum to confirm 10 Hz filter criteria and 1/2 second time criteria

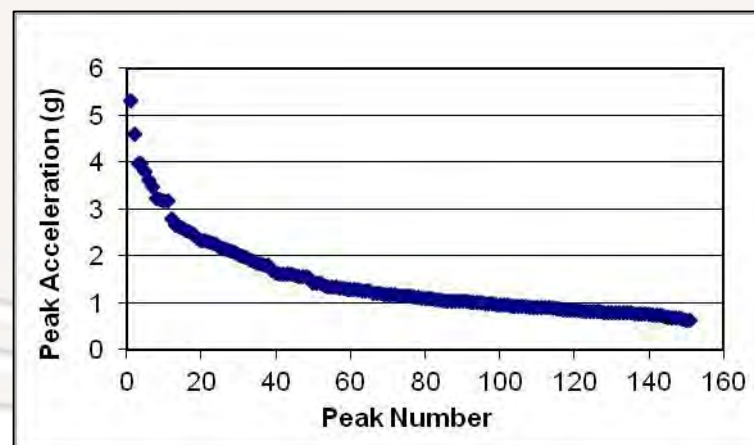
Step 2 Apply 10 Hz low pass filter and compute RMS



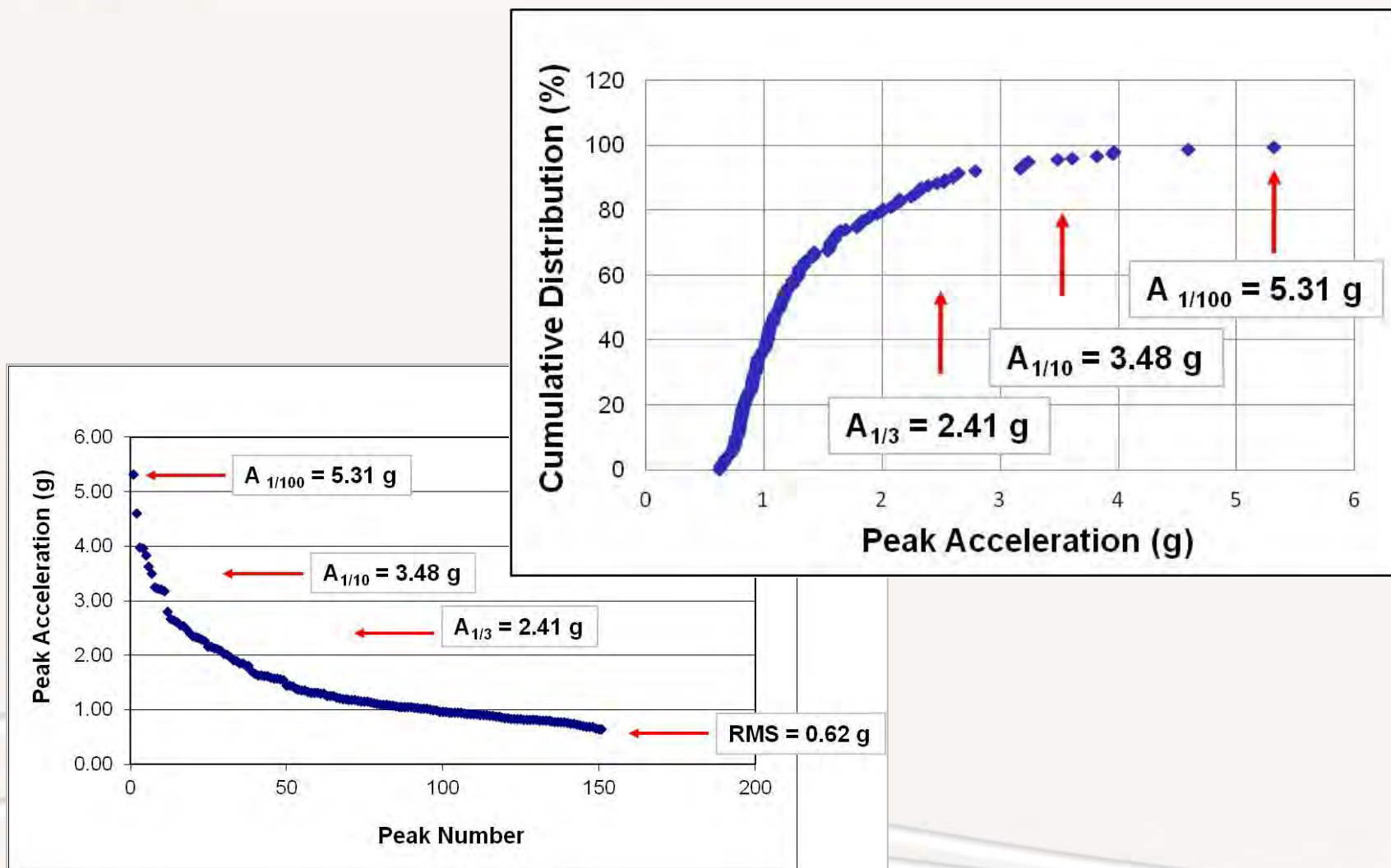
Step 4 Compute statistical values

$5.31g = A_{1/100}$
 $3.48g = A_{1/10}$
 $2.41g = A_{1/3}$
 $0.62g = \text{RMS}$

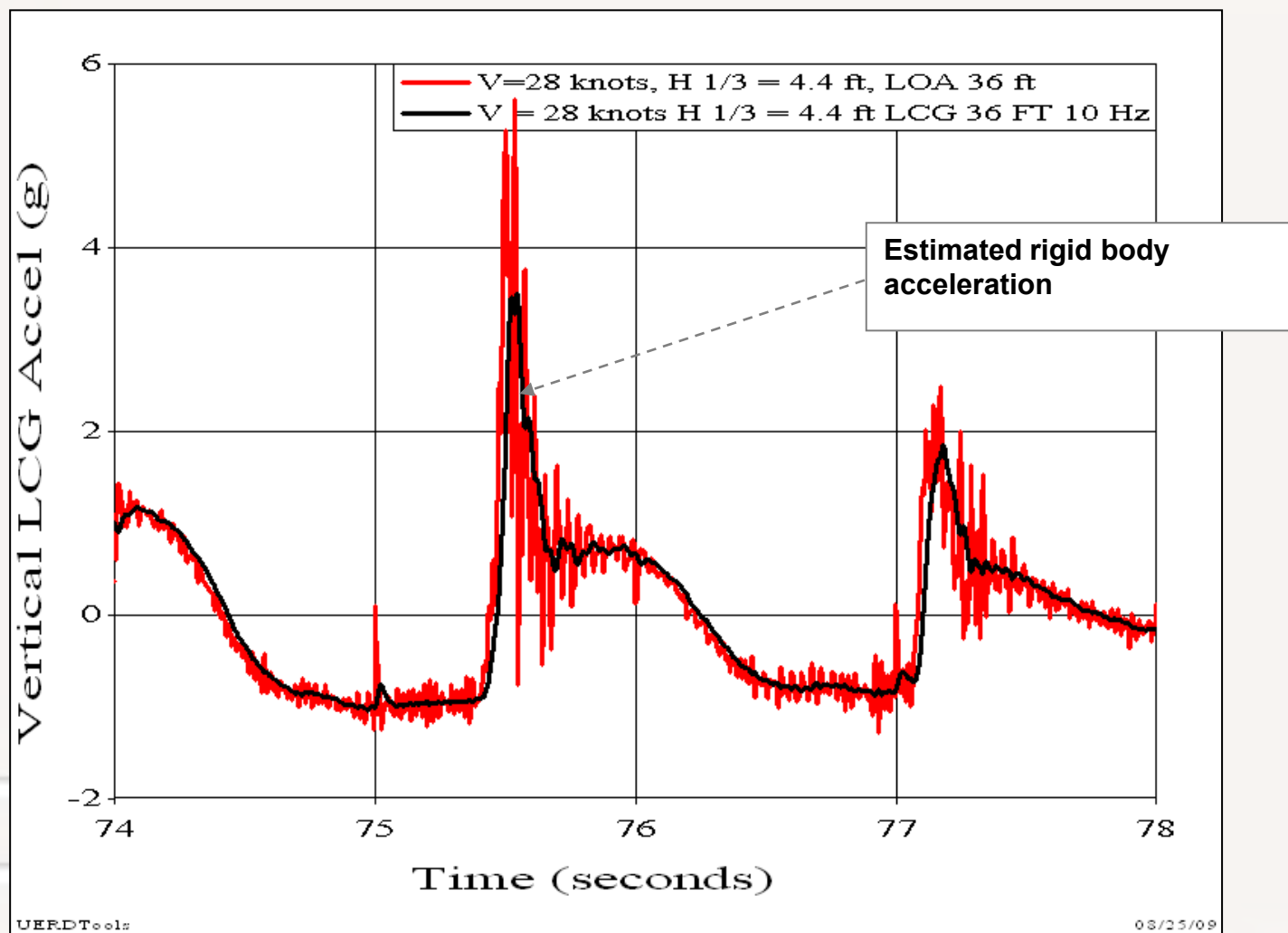
Step 3 Extract peaks with PKT algorithm using RMS vertical threshold and 1/2-second time threshold



Average $A_{1/n}$ Accelerations

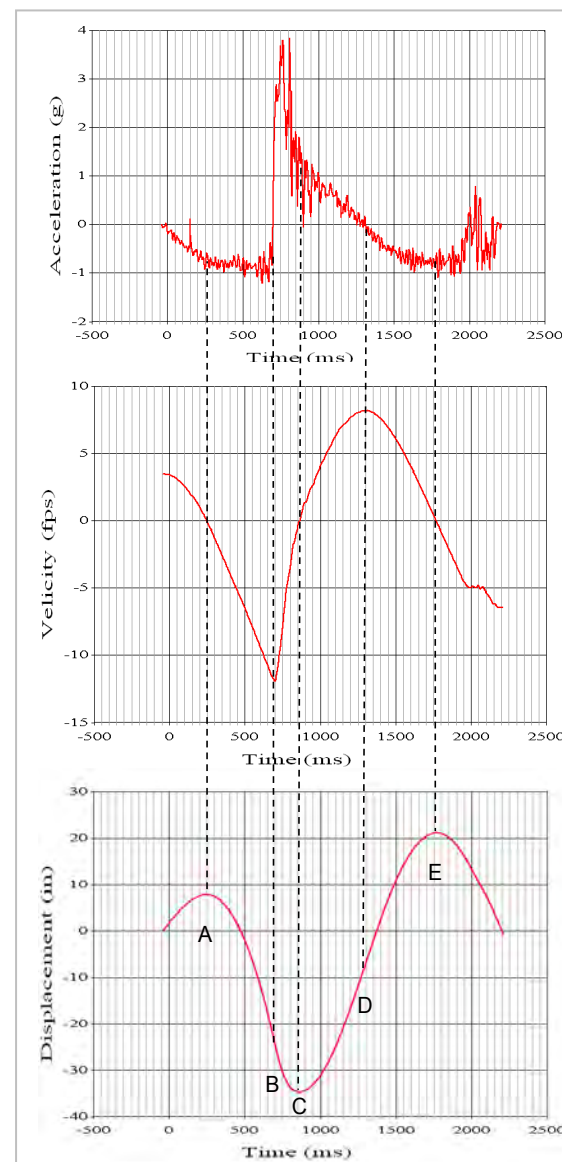


Filtered vs Unfiltered Wave Encounters

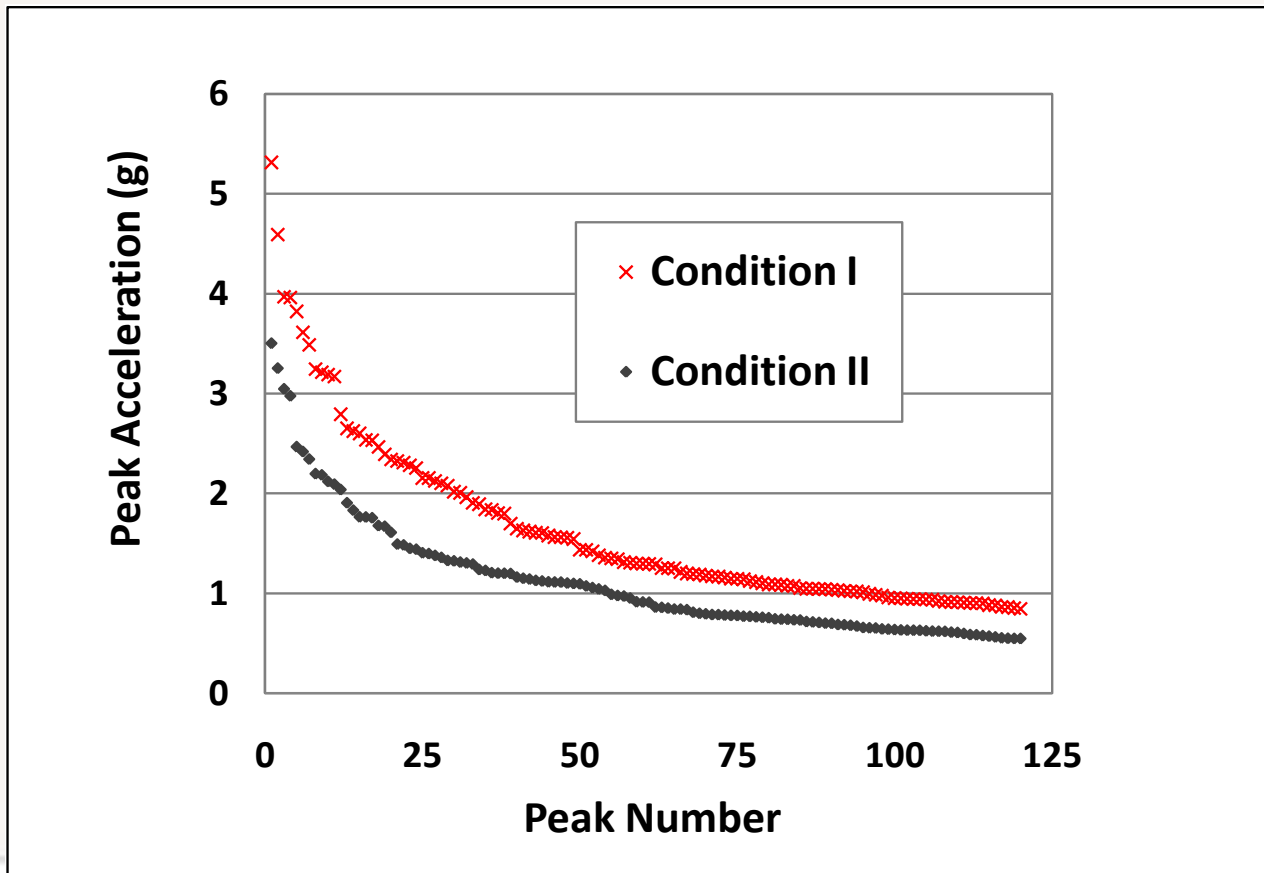


Single Impact

<u>Time</u>	<u>Response</u>
A to B	<ul style="list-style-type: none"> • Close to gravity free-fall (-) • Estimate of drop height prior to impact
B	<ul style="list-style-type: none"> • Maximum downward velocity • Time of initial water impact
B to C	<ul style="list-style-type: none"> • Craft moving down in water • Maximum loading phase • Wave slam period
C	<ul style="list-style-type: none"> • Time of maximum downward velocity • Instantaneous velocity = 0 • Loading reduced to ambient
C to D	<ul style="list-style-type: none"> • Upward hydro-dynamic force • Upward buoyant force • Upward thrust vector • Force upward stops at D

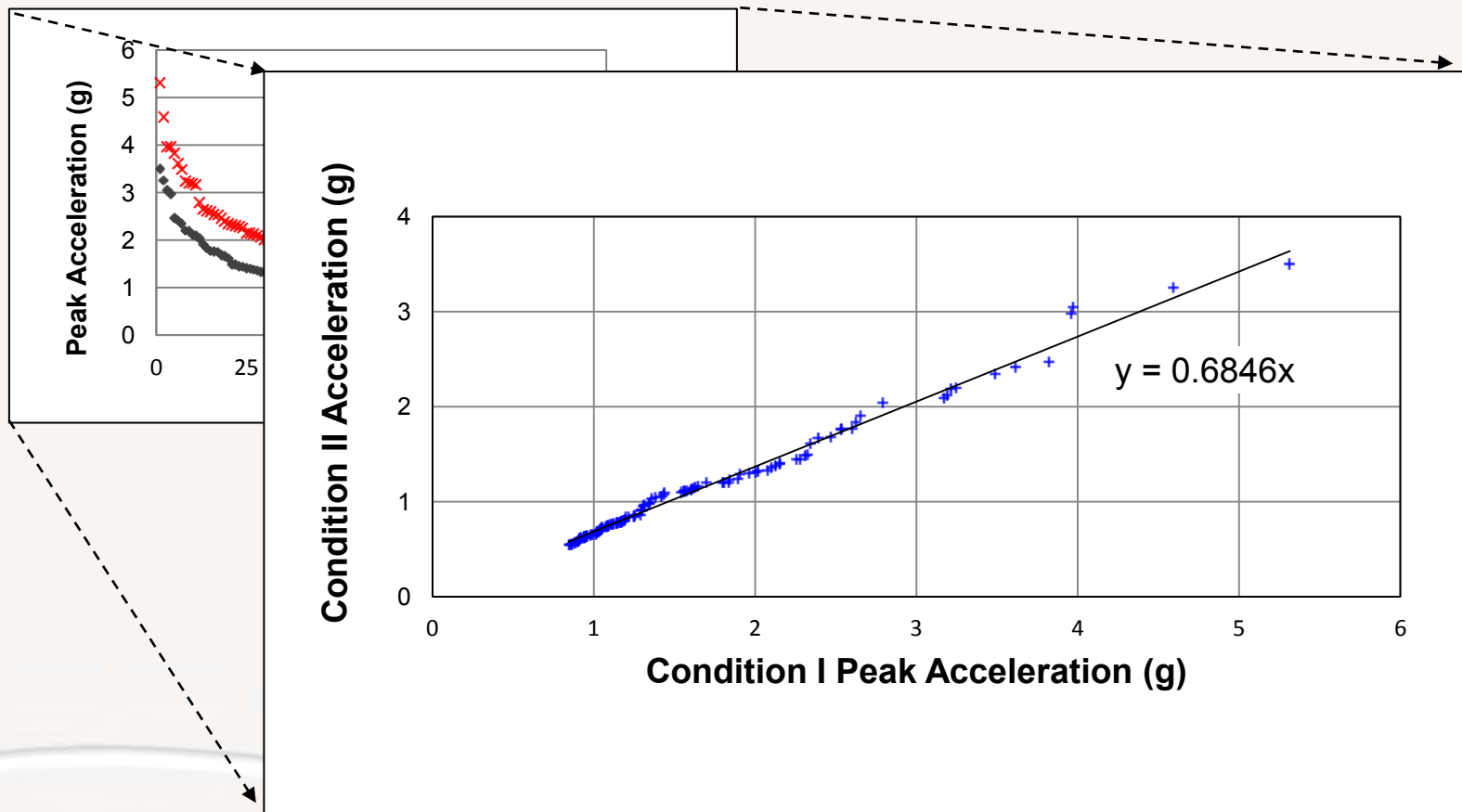


Peak Acceleration Comparison



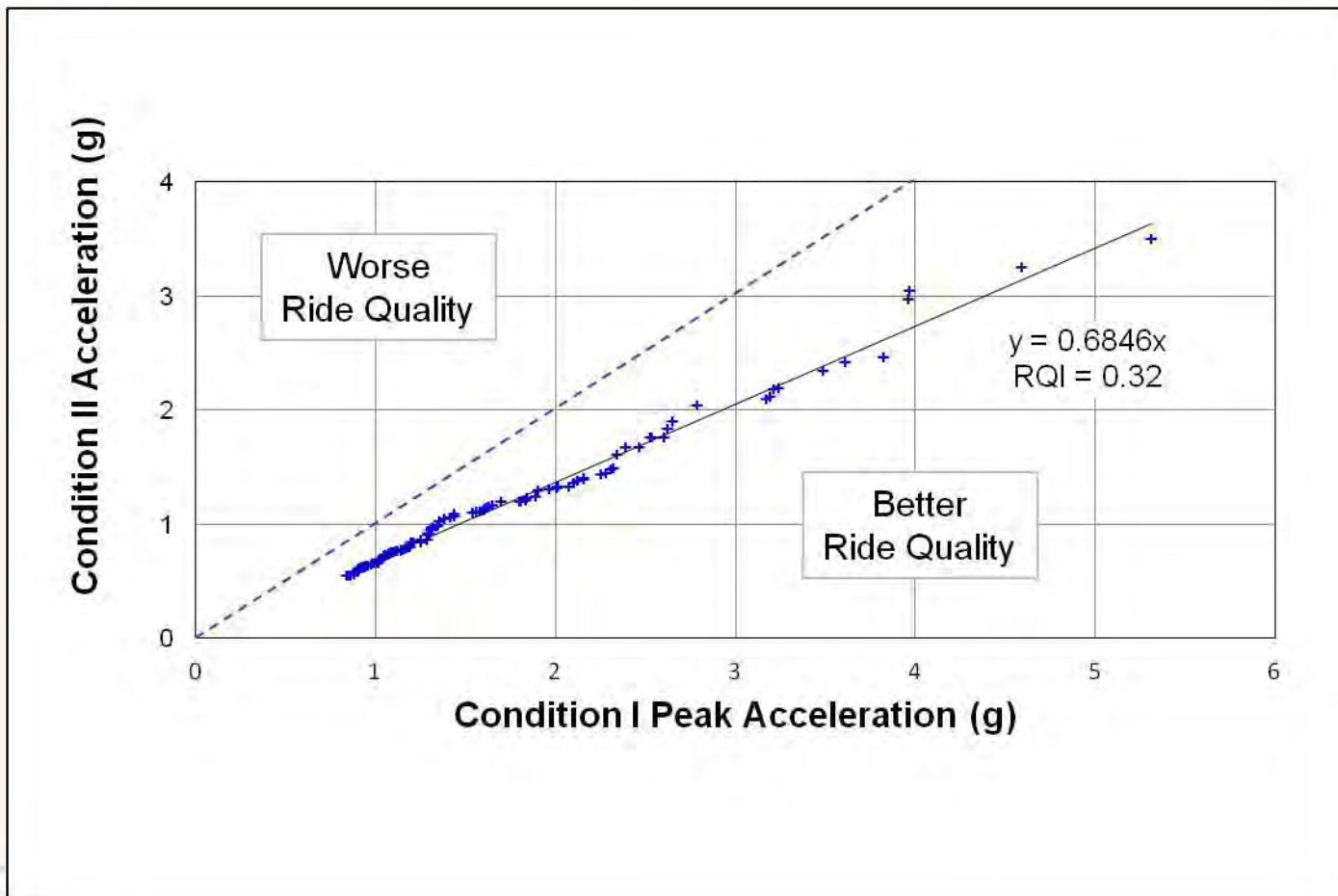
Test Condition Variables: different craft, speeds, wave heights, gage locations

Different Comparison Format



The least squares linear fit has a zero intercept

Ride Quality Index



$$Ride\ Quality\ Index\ (RQI) = 1 - \frac{\Delta A_{ConditionII}}{\Delta A_{ConditionI}}$$

Why “Acceleration Ratio” ?

Damage Categories

Structural Damage
Equipment malfunction or failure
Crew discomfort or injury

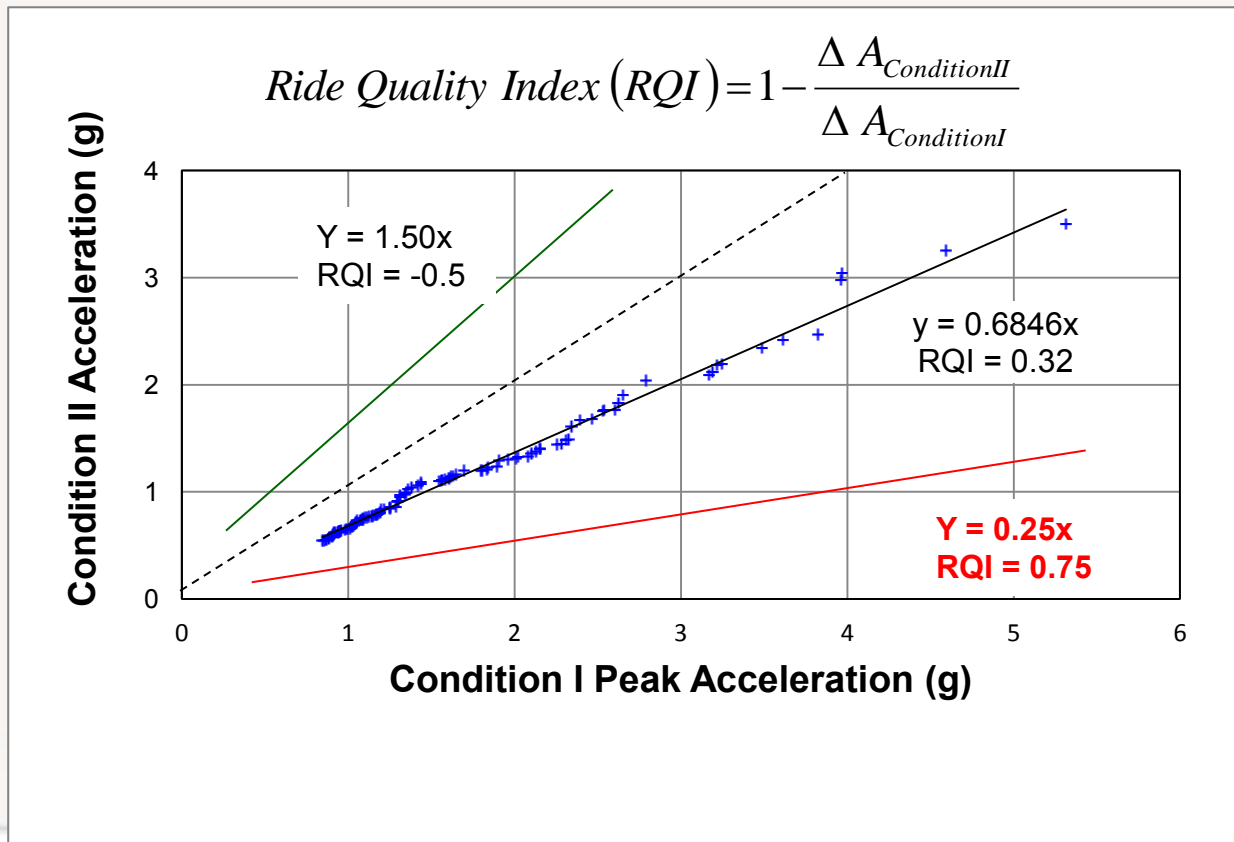
$$(Damage\ Potential)_{Shock} \propto (\Delta\ Rigid\ Body\ Velocity)$$

$$\frac{A_{RBII}}{A_{RBI}} \approx \frac{\Delta V_{RBII}}{\Delta t_{RBII}} \bigg/ \frac{\Delta V_{RBI}}{\Delta t_{RBI}}$$

If Δt_i is relatively constant... then $\frac{A_{II}}{A_I} \approx \frac{\Delta V_{RBII}}{\Delta V_{RBI}}$

$$RQI = 1 - \frac{A_{II}}{A_I} = 1 - \frac{\Delta V_{II}}{\Delta V_I} \propto \frac{1}{Damage\ Potential}$$

Ride Quality Index = $f(\text{Damage potential})^{-1}$



$$\frac{A_{II}}{A_I} \uparrow \rightarrow \text{Damage Potential} \uparrow \rightarrow RQI \downarrow$$

$$\frac{A_{II}}{A_I} \downarrow \rightarrow \text{Damage Potential} \downarrow \rightarrow RQI \uparrow$$

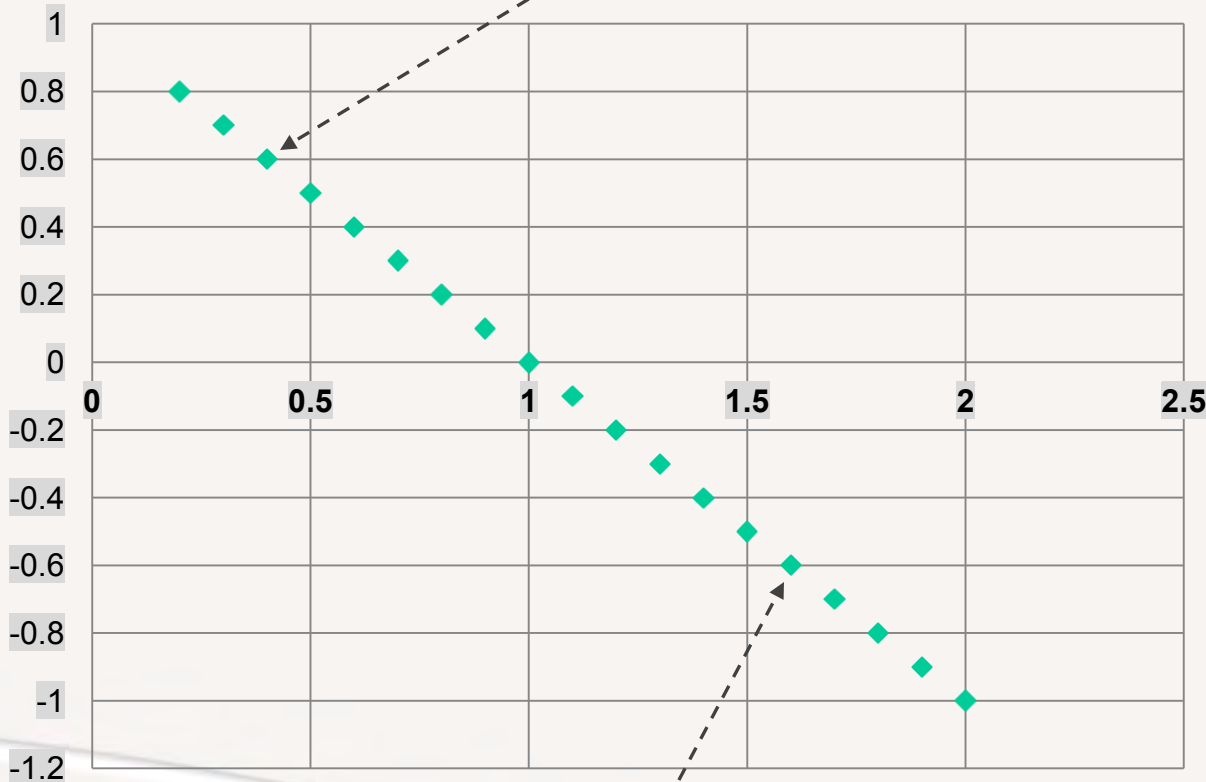
RQI vs Acceleration Ratio

RQI

Better
Ride

Same

Worse
Ride



RQI = +0.6 means 60% less than baseline (better ride)

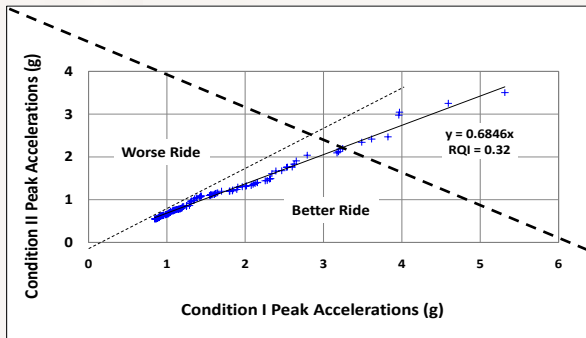
RQI = - 0.60 means 60% greater than baseline (worse ride)

$$\frac{A_{II}}{A_I}$$

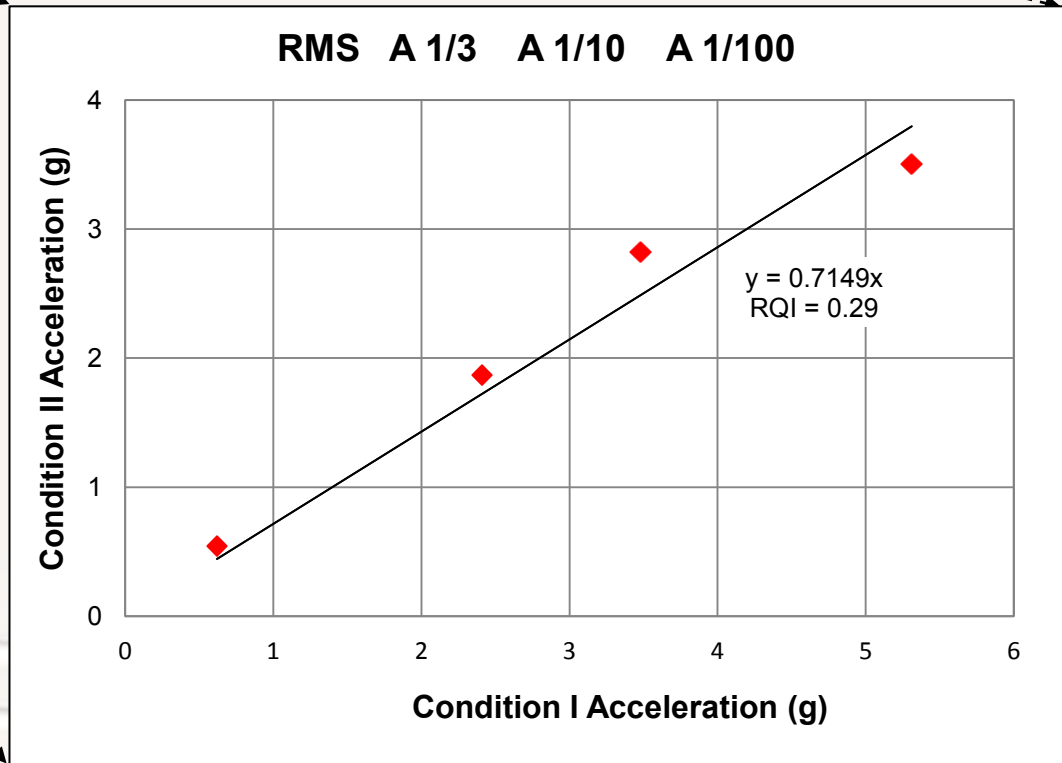
Ride Quality Index Using $A_{1/n}$ Ratios

Carderock

$$RQI_{1/10} = 1 - \frac{(A_{1/10 II} - 0)}{(A_{1/10 I} - 0)}$$

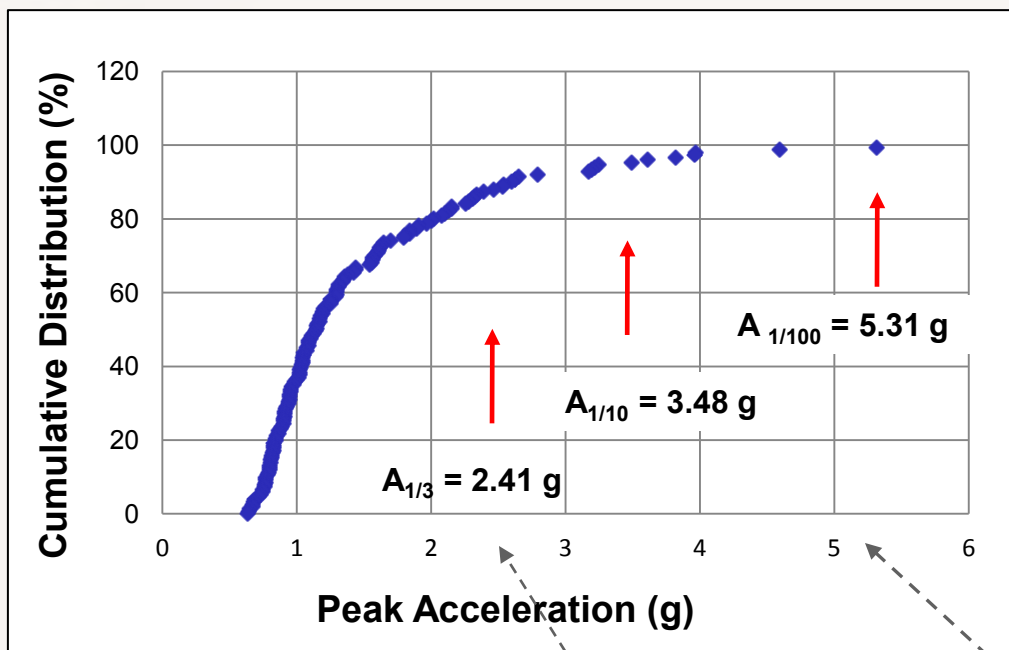


Test	Condition I	Condition II	Ride Quality Index
A 1/100	5.31 g	3.50 g	0.34
A 1/10	3.48 g	2.82 g	0.19
A 1/3	2.41 g	1.87 g	0.24
RMS	0.62g	0.54g	0.13
1-Slope	na	na	0.29



Simple Damage Mechanisms

Carderock

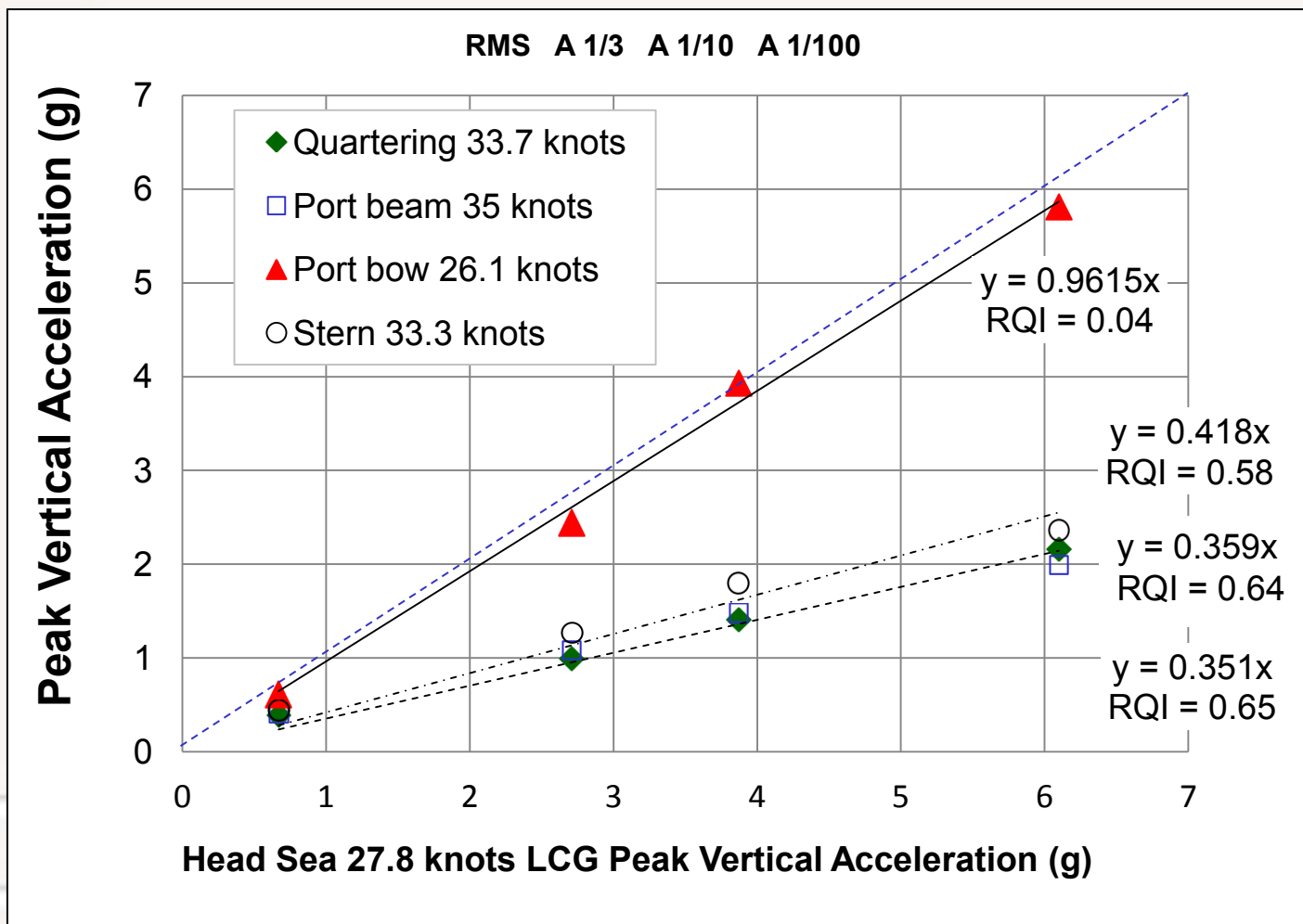


Test	Condition I	Condition II	Ride Quality Index
A 1/100	5.31 g	3.50 g	0.34
A 1/10	3.48 g	2.82 g	0.19
A 1/3	2.41 g	1.87 g	0.24
RMS	0.62g	0.54g	0.13
1-Slope	na	na	0.29

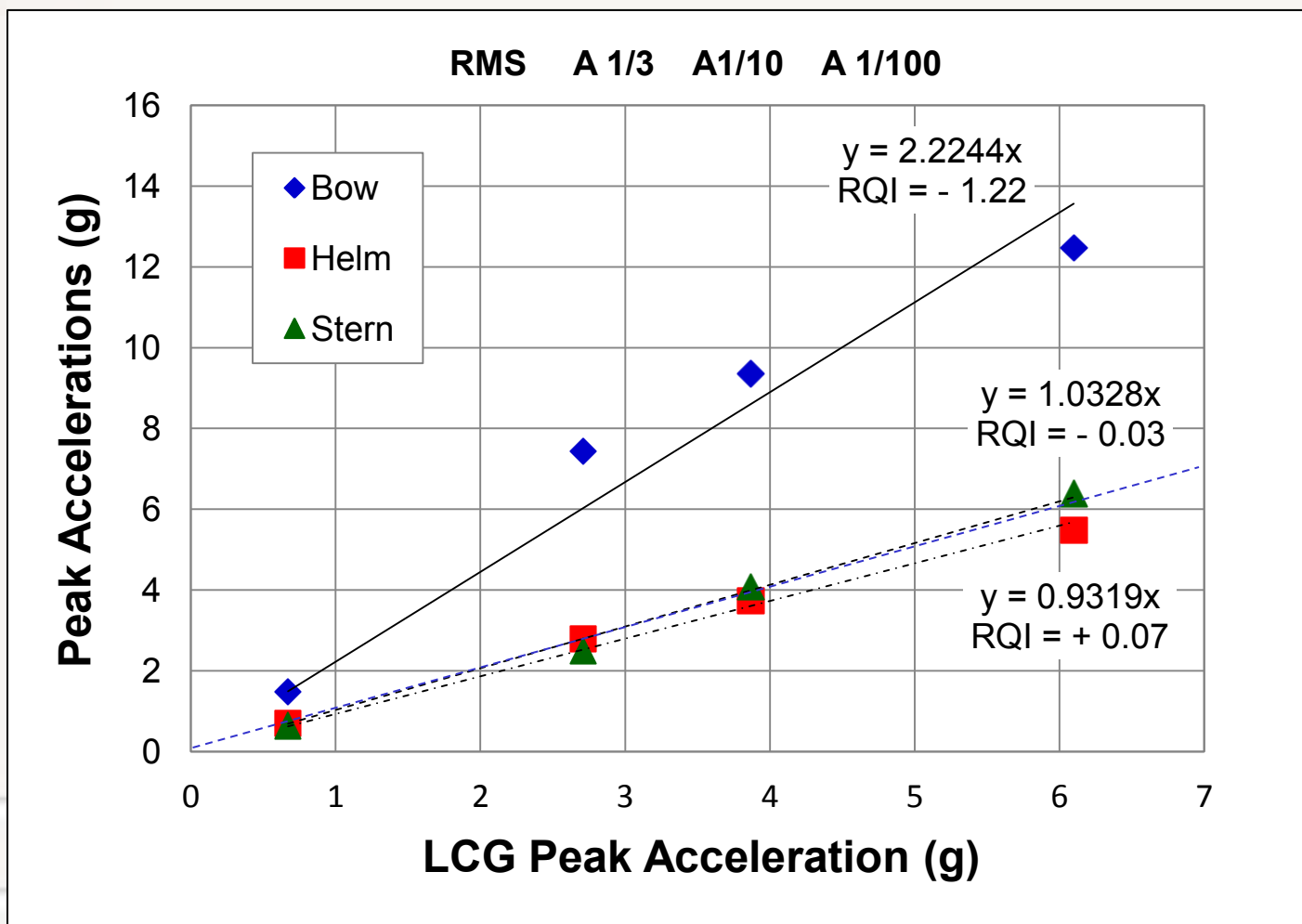
Failures due to cyclic lower amplitude wave slams (shock) could be caused by electrical disconnects of plugs, sockets, or circuit cards

Failures due to severe (large amplitude) wave slams (shocks) could be caused by material over stresses or disconnects

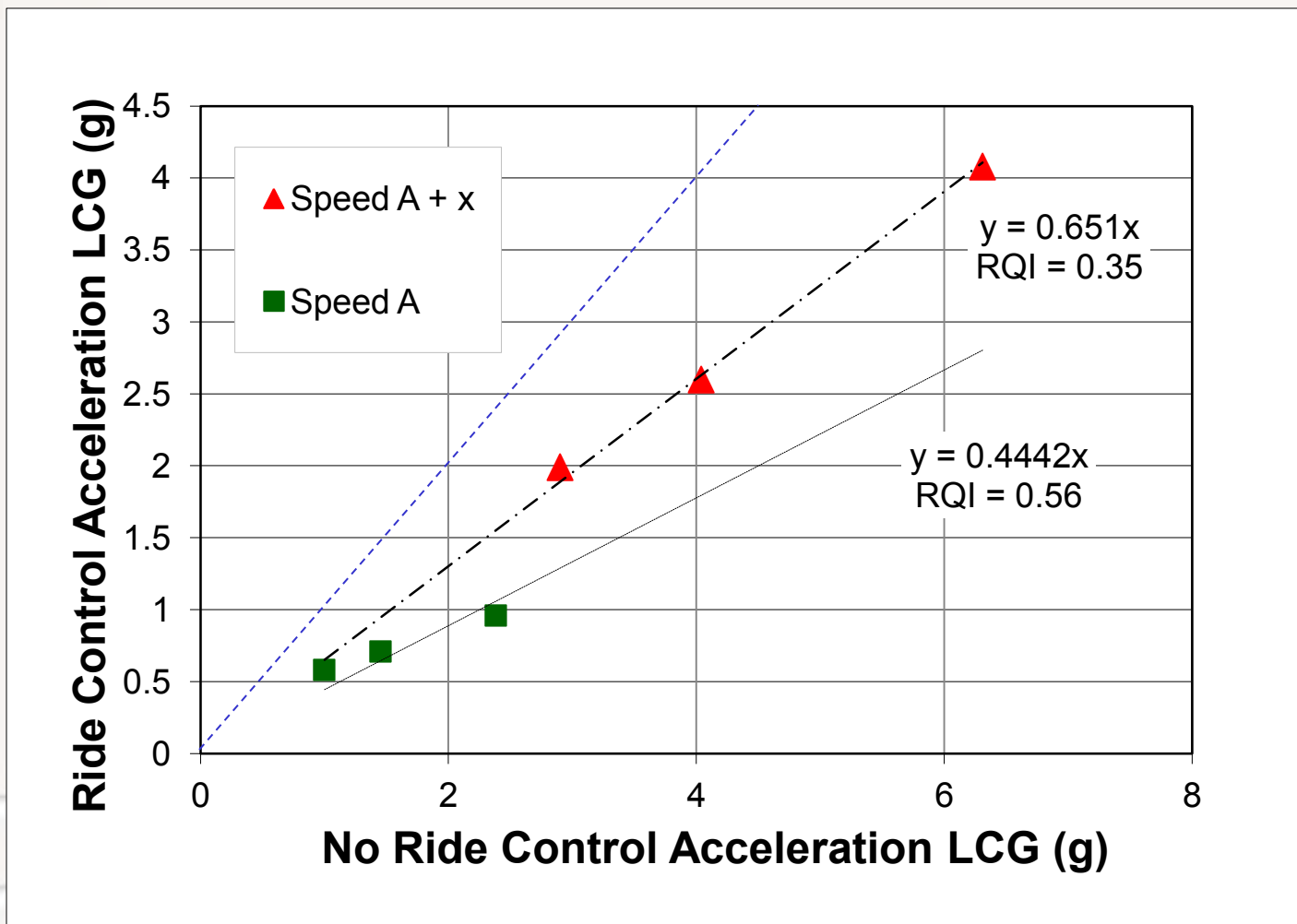
Example: Same Craft Different Headings



Example: Same Craft Different Gage Locations



Example: Two Craft - Ride Control Comparison



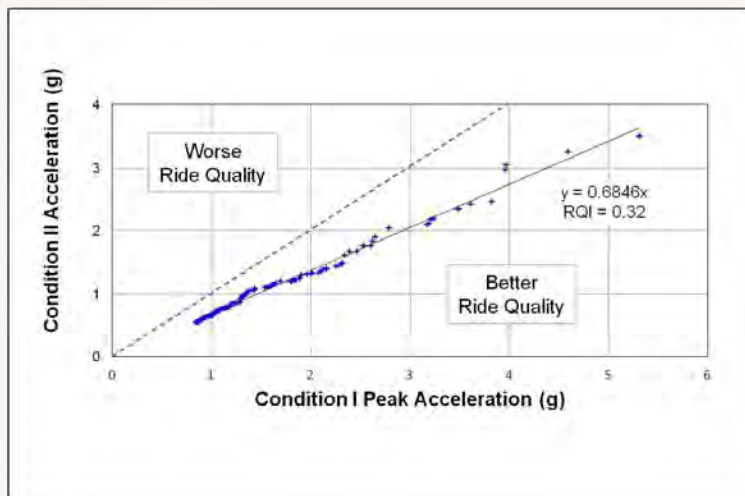
Observations

- Use of RQI requires consistent data processing
 - Generalized $A_{1/n}$ process
- New approach
 - Use of all peak accelerations
 - Or, use of all statistics (RMS, $A_{1/3}$, $A_{1/10}$, $A_{1/100}$), not one level
- Also applicable to pitch, roll, pitch or roll rates
- Useful to quantify a skilled operators perception
- Compare craft responses regardless of the source of the data, when generalized $A_{1/n}$ process used

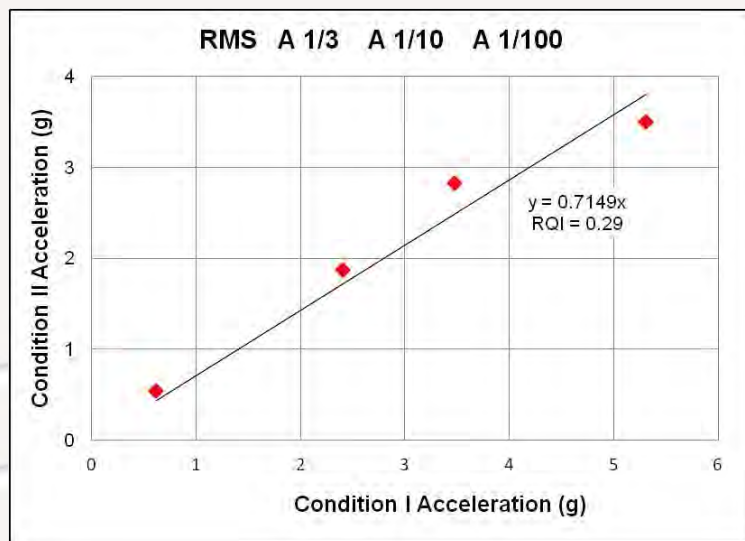
Summary

- Applied a 4-step computational process for repeatable $A_{1/n}$ calculations
- Introduced a simple Ride Quality Index
 - New combined use of all peaks, RMS, $A_{1/3}$, $A_{1/10}$, $A_{1/100}$
 - Proportional to wave slam (shock) damage potential
 - Cumulative damage or single-severe slam affects
 - Useful tool for better/worse ride quality comparisons
- Use of standardized $A_{1/n}$ calculation and RQI may foster future comparisons of ride quality of different craft or different test conditions regardless of the source of the data

Questions



$$Ride\ Quality\ Index\ (RQI) = 1 - \frac{\Delta A_{ConditionII}}{\Delta A_{ConditionI}}$$



Test	Condition I	Condition II	Ride Quality Index
A 1/100	5.31 g	3.50 g	0.34
A 1/10	3.48 g	2.82 g	0.19
A 1/3	2.41 g	1.87 g	0.24
RMS	0.62g	0.54g	0.13
1-Slope	na	na	0.29